

# **NASA Environmentally Responsible Aviation's Highly-Loaded Front Block Compressor Demonstration**



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Lead,  
High OPR Compressor Demonstration**

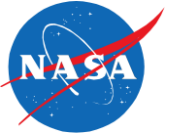
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**Collaborative NASA/GE Partnership**

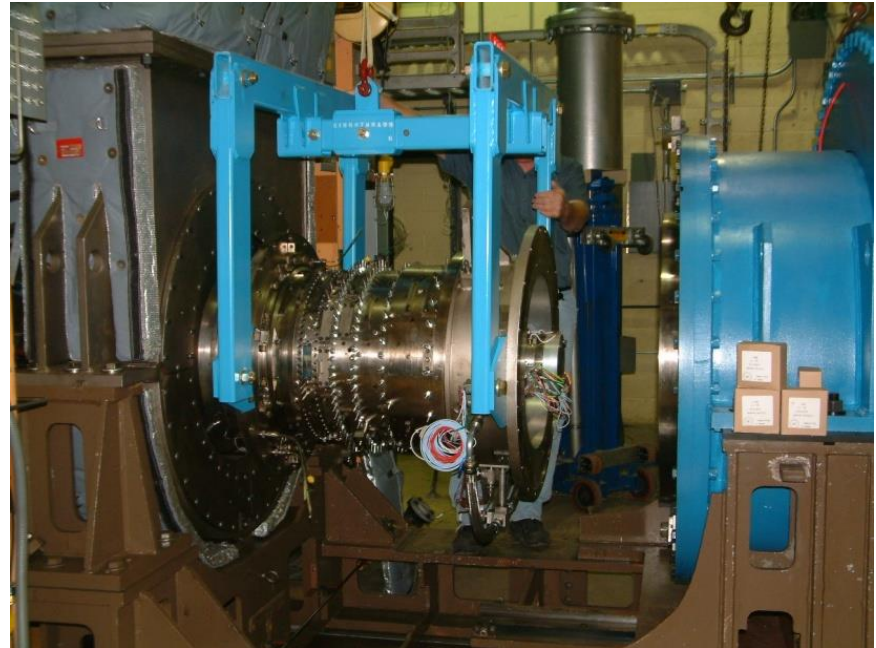
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# Outline

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- Mgmt by Tech Challenge
- Thermal Efficiency Improvement Through Higher OPR
- W7 Test Facility
- Phase I Test Setup
- Phase 1 Summary
- Phase 2 Plan
- Phase 2 Results
- Summary/Closing Remarks



# Management by Technical Challenge



**TFA3: Advanced UHB Engine Designs for Specific Fuel Consumption and Noise reduction**

**TC3 – Demonstrate UHB efficiency improvements to achieve 15% TSFC reduction, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while reducing engine system noise and minimizing weight, drag, NOx and integration penalties at AC system level**

## Need

Increased engine system overall pressure ratio (OPR) for reduced fuel consumption while reducing engine system noise and minimizing weight, drag, NOx, and integration penalties at the aircraft system level

## Goal

Demonstrate front block compressor technologies to enable high pressure ratio (30:1) core compressors for a 2-3% reduction in SFC (specific fuel consumption)

## Success Criteria

- Minimum Success – Test & document the performance (PR and Efficiency) and operability (Stall Margin) of the first 3 stages of a 30:1 PR class high pressure compressor (HPC)
- Full Success – Minimum success plus demonstrate performance improvements (in PR and/or Efficiency) of the first 3 stages of a 30:1 PR class HPC while maintaining operability

## Objectives

- Design and test a three-stage front block, 30:1 class HPC to meet minimum efficiency and operability requirements
- Design and test an improved front block that shows higher pressure ratio at a constant efficiency while meeting the same operability requirements
- Validate design methodology against experimental measurements
- Measure the performance (pressure ratio and temperature ratio vs. mass flow) of a three-stage front block of a HPC design
- Validate required operability with increased stall margin and improved aeromechanic response

## KPP2025 & TRL

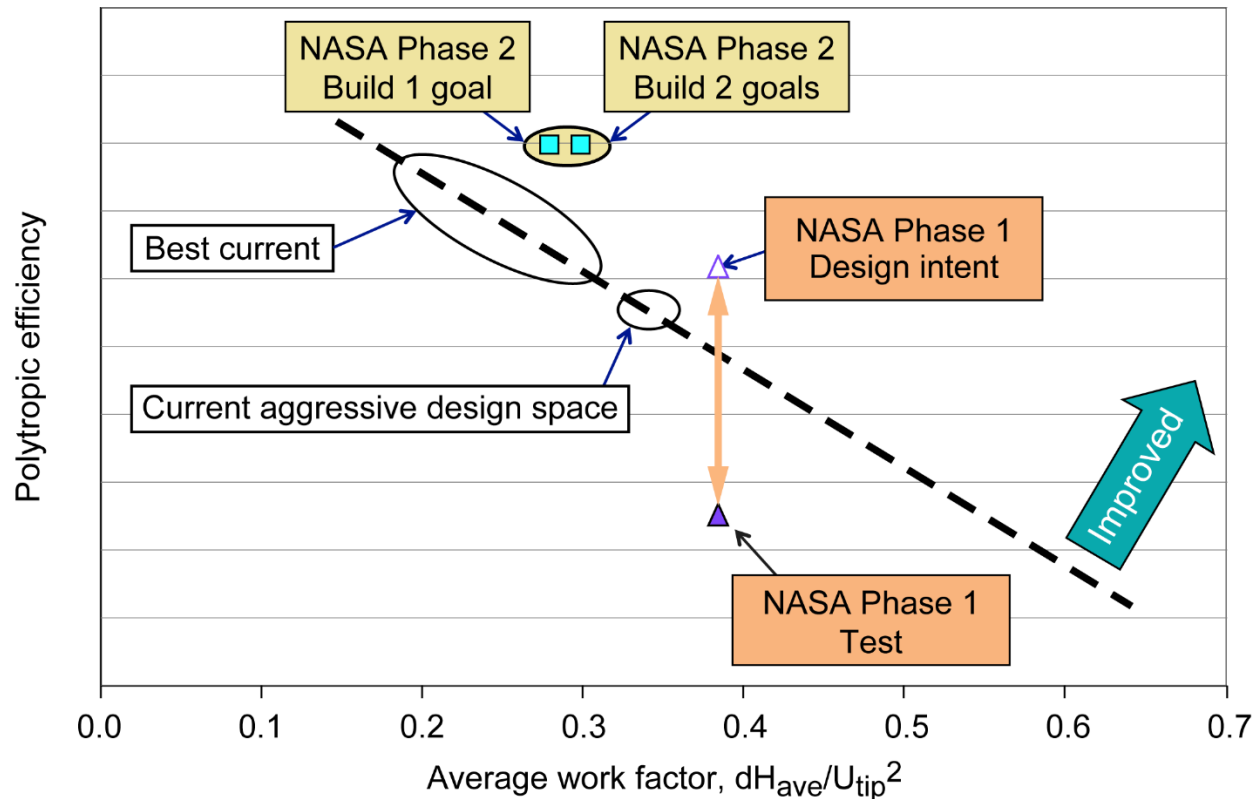
- Reduce TSFC by 2.5%
- TRL 3 to 5

## Key Deliverables

- HPC front block performance and operability data for baseline and advanced configurations
- Compressor map data delivered to systems analysis team
- Technology maturation report

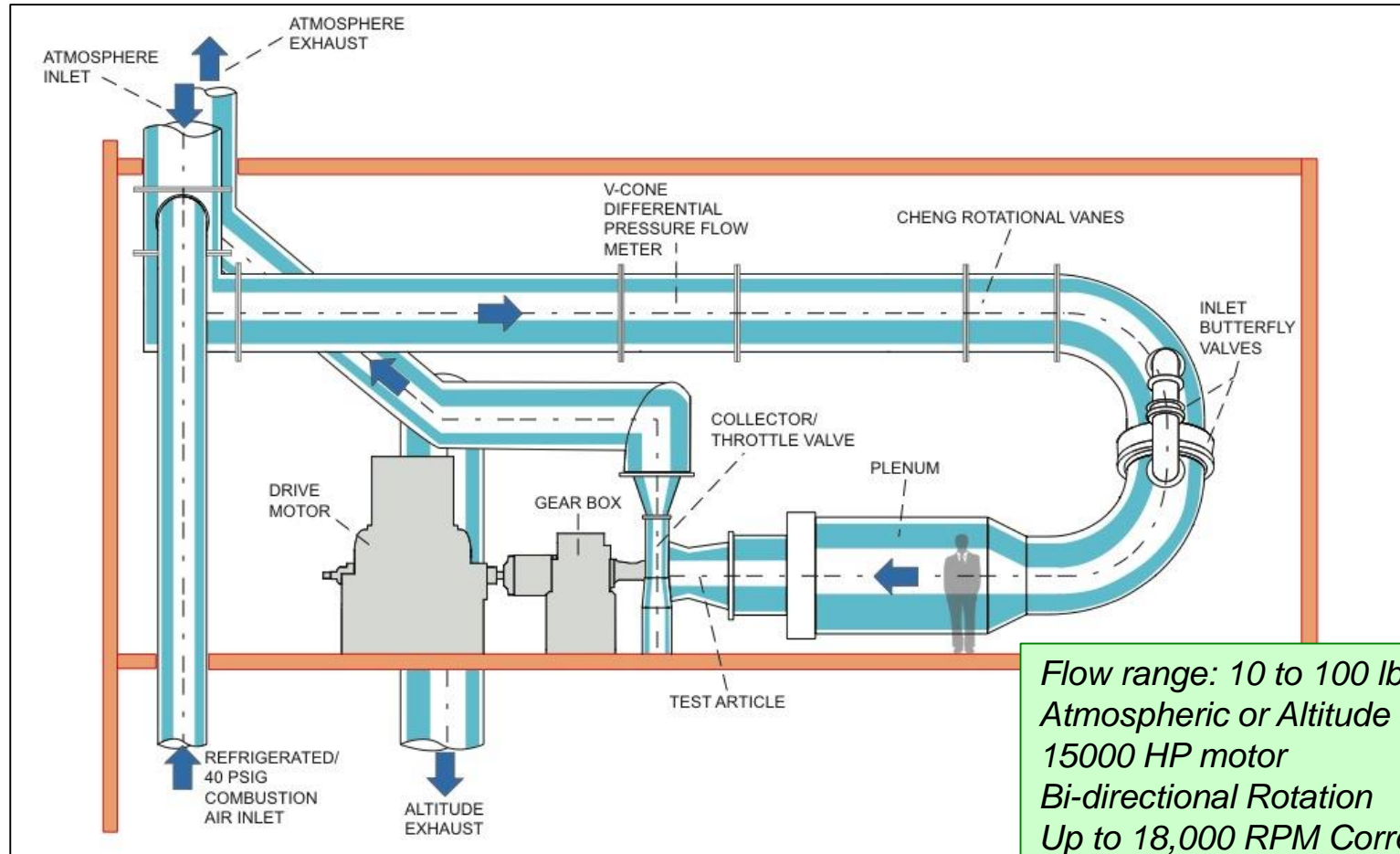
## Applicability

- High-power density, high thermal efficiency cores that enable UHB systems
- Scalable across all current, advanced and unconventional aircraft configurations and size classes



**Phase 2 Goals were Achieved Based on Leveraging Phase 1 Understanding.**

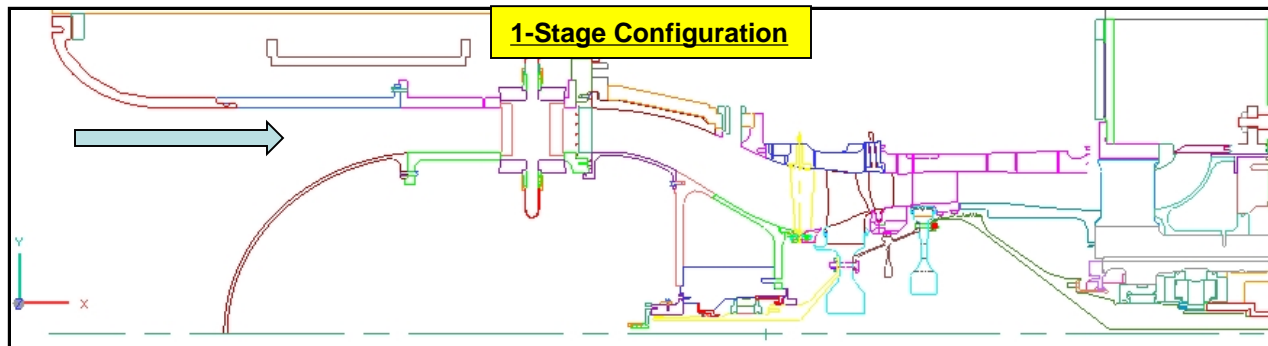
# Test Facility – NASA GRC W7 Multistage Test Cell



**Upgrades Made to W7 for Flow Quality & Mass Flow Measurement Accuracy**



# Phase 1 Test Setup



## Phase 1 Blading Design

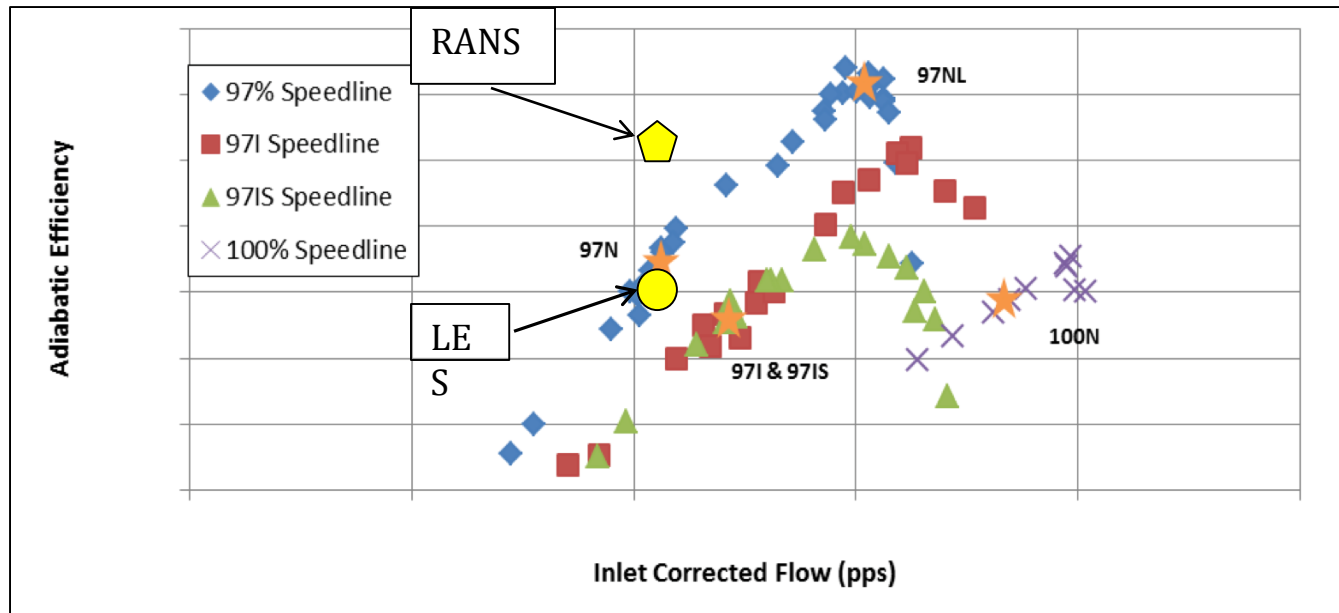
Legacy hardware/Aggressive design  
Rotors supersonic from root to tip  
Low efficiency not captured by CFD

### Challenge: Understand Phase 1 front block aerodynamic loss mechanisms

- ✓ Designed an experiment to uncouple a 1-stage and 2-stage configuration to unravel the source of efficiency loss in highly loaded compressors
- ✓ Generate a high quality data set to perform post-test data matching and CFD analysis to try and analytically predict the measured loss and inefficiency

**Purpose: Understand high stage loading HPC front stage loss mechanisms**

# Phase 1 Summary

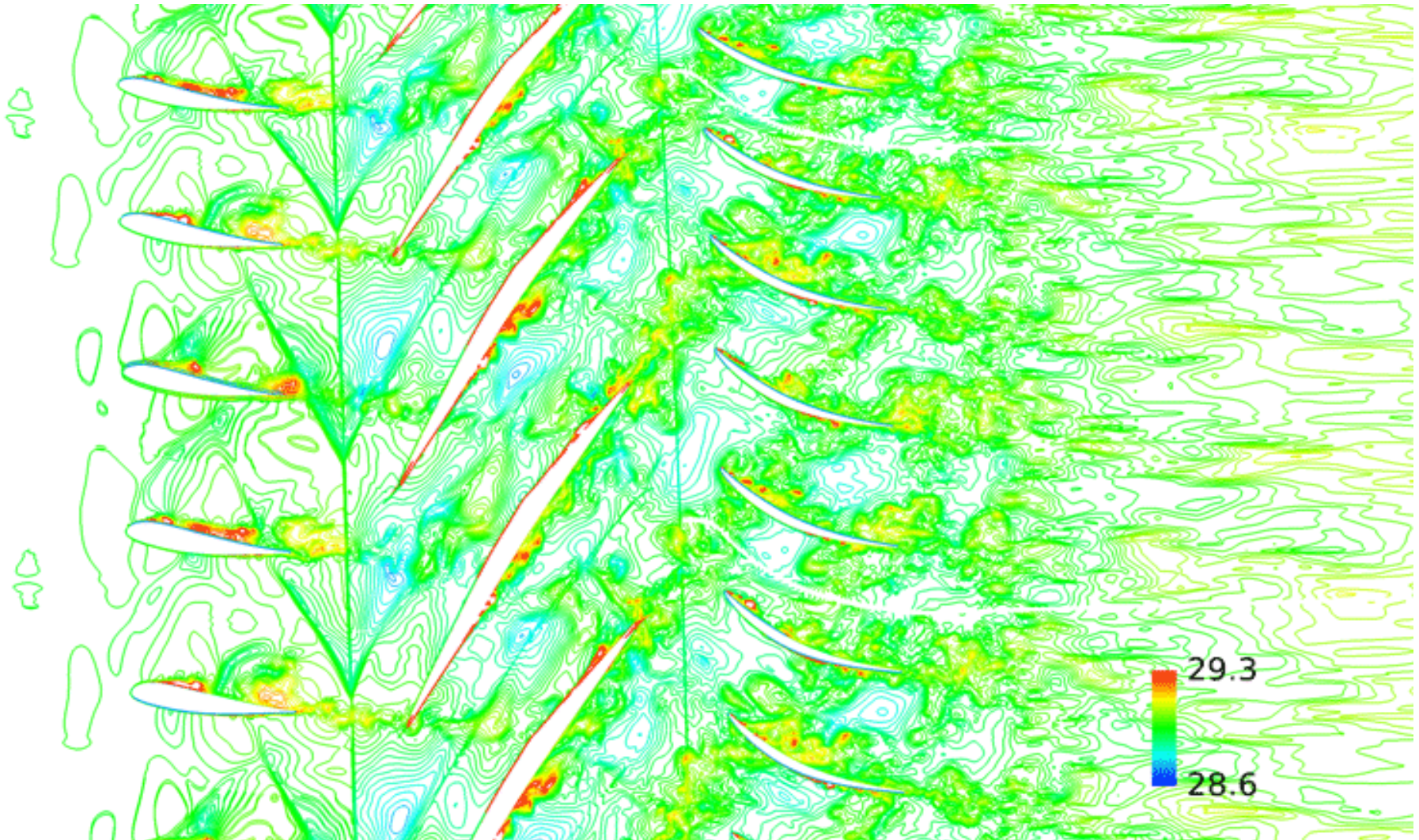


- Analysis shows the loss source is isolated to within the single stage configuration
- RANS CFD (steady and unsteady) doesn't seem to capture the measured losses
- Initial LES results show promise to capture the loss source

- ✓ Continue to post-process the detailed data and compare to CFD simulations
- ✓ Run LES without IGV to isolate the loss source

# IGV/Rotor/Stator Simulation (NASA LES Code)

## Entropy generation at mid-span





# Phase 2 Plan



**Minimum Success:** Demonstrate front block compressor technologies to enable HP core compressors for a 2-3% reduction in SFC

**Build1 = Baseline**

**Full Success:** Min Success + demonstrate a performance improvements in PR and/or Efficiency while maintaining operability

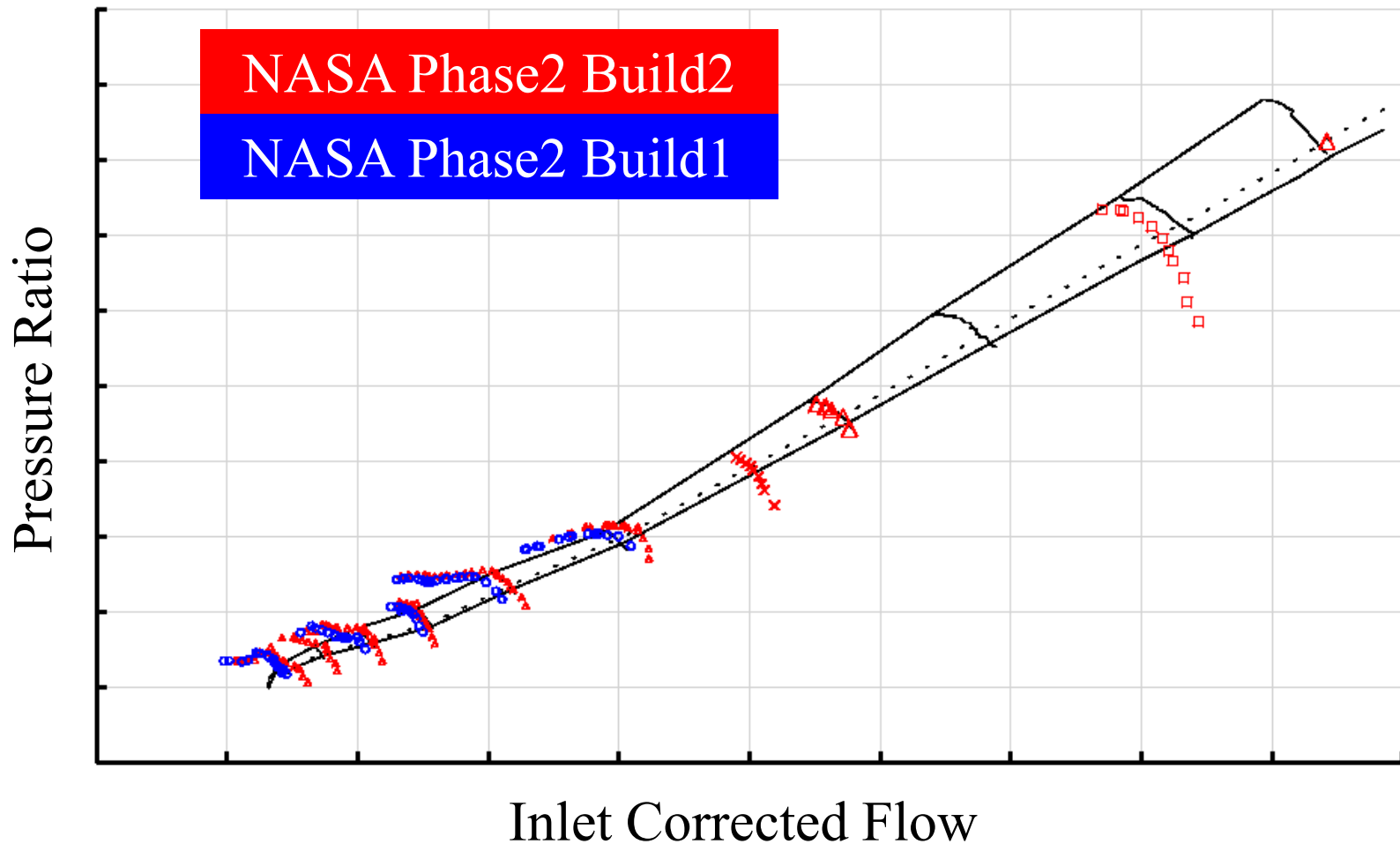
**Build2 = Redesigned Blades**

Baseline Installed in W7



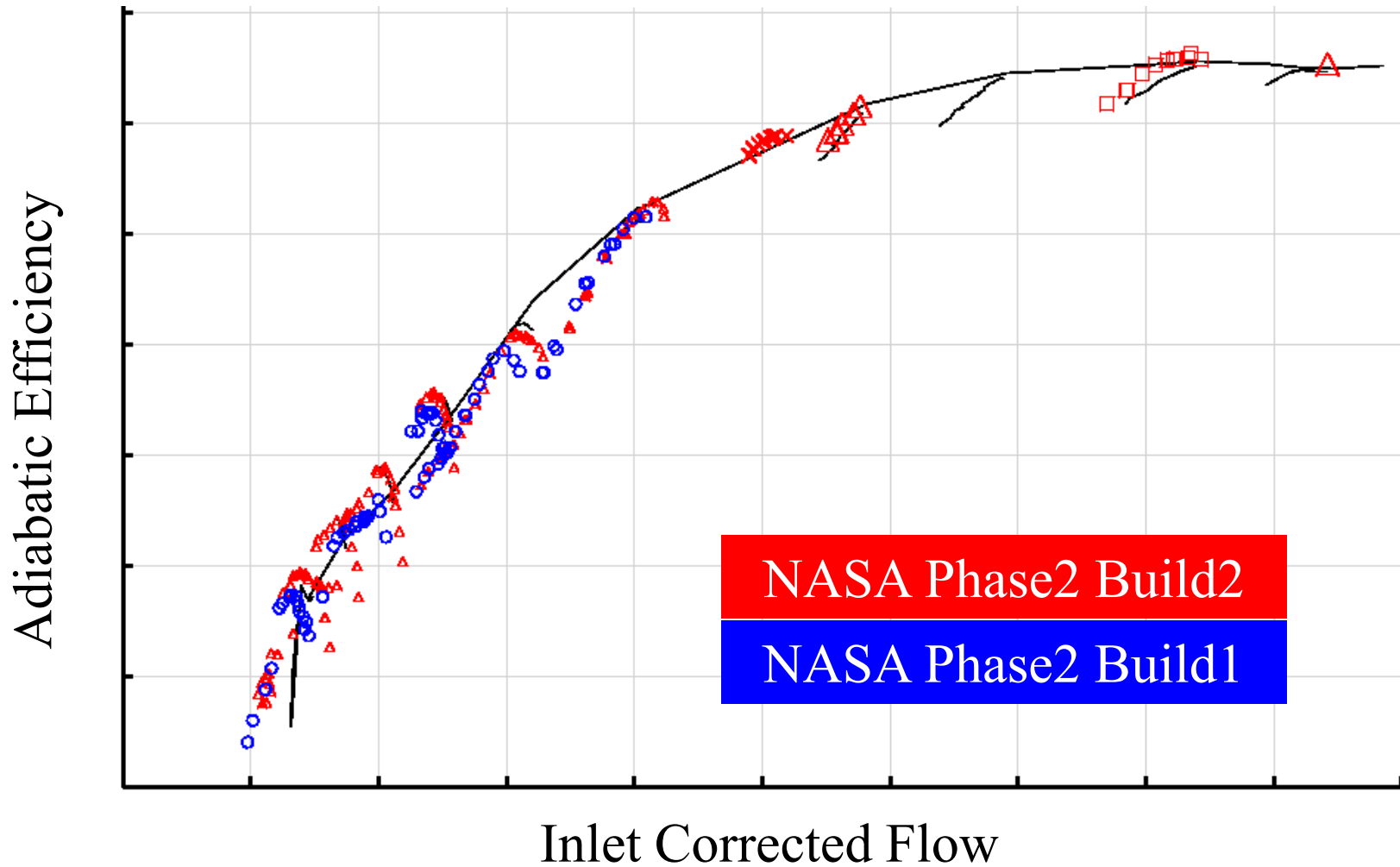
**Full success achieved as was the goal of 2.5% TSFC reduction for the technology.**

# PR vs. Inlet Corrected Flow



- Build 1 hardware defects prevented full speed operation
- Build 2 fully successful by capitalizing lessons learned from Build 1

# Ad. Eff. vs. Inlet Corrected Flow



Goal: 2.5% TSFC Reduction    Achieved: 2.94% TSFC Reduction

# Summary & Closing Remarks



- **ERA investment in W7 successful in mitigating test risks. Provides unique and versatile facility for SOA multistage compressors and experienced personnel to execute future test campaigns.**
  - **Phase 1 Lessons Learned Implemented as Phase 2 Risk Mitigation**
    - **Speed control worked well**
    - **Cross-talk eliminated between inlet and exhaust**
    - **Oil leaks eliminated from Phase 1 testing**
- **Min & Full Success Criteria Met despite cascading issues related to fabrication slips / schedule slips / assembly issues.**
- **Propulsion Technology Accomplishments**
  - ✓ TRL 5 demonstration of highly-loaded front block compressor technology.
  - ✓ Achieved Full Success (demo of a Baseline and PIP compressors)
  - ✓ Exceeded TSFC Reduction Goals
- **Phase II built on Phase I: Leveraging Integrated Technology Development / Demonstration coupled with systems analysis and incorporation of Advanced Vehicle Concepts**